

Mushroom Intake is associated with Better Nutrient Intake and Diet Quality: 2001-2010 National Health and Nutrition Examination Survey

Carol E O'Neil^{1*}, Theresa A Nicklas² and Victor L Fulgoni III³

¹Class of 1941 Alumni Professor, Louisiana State University Agricultural Center, Baton Rouge, Louisiana 70803, USA

²USDA/ARS Children's Nutrition Research Center, Department of Pediatrics, Baylor College of Medicine, Houston, Texas 77030, USA

³Nutrition Impact, LLC, Battle Creek, Michigan 49014, USA

Abstract

Background: The association between mushroom consumption and nutrient intake or diet quality has not been reported. The purpose of this study was to determine the associations between these variables in a nationally representative sample of adults.

Methods: Dietary intake was determined using a 24-hour recall on adult 19+ year (N=24,807) participants of the National Health and Nutrition Examination Survey 2001-2010. Mushroom consumption was defined in two ways: 1) intake of food codes (n=281) including mushrooms and 2) intake of food codes (n=32) designated as "mushrooms". Sample weighted, covariate-adjusted least square means \pm SE were determined and compared using t-tests ($p < 0.01$). Diet quality was calculated using the Healthy Eating Index-2005 (HEI).

Results: For consumer definitions 1 and 2, respectively: among consumers, mushroom consumption was 20.6 ± 0.75 g/d (n=2,399) and 39.5 ± 2.6 g/d (n=460). For definition 1: mushroom consumers had higher ($p < 0.01$) intakes of energy, protein, thiamin, niacin, folate, copper, selenium, and sodium, and lower intakes of total and added sugars. HEI-2005 was higher among consumers 52.4 ± 0.4 v 51.3 ± 0.2 . For definition 2: mushroom consumers had higher ($p < 0.01$) intakes of protein, fiber, vitamin E, riboflavin, niacin, vitamin C, total choline, copper, potassium, selenium, and sodium than non-consumers. Mushroom consumers had lower ($p < 0.01$) intakes of added sugars and a higher ($p < 0.01$) total HEI-2005 score (54.6 ± 0.9 v 51.4 ± 0.2) than non-consumers.

Conclusions: Mushroom consumption was positively associated with higher intake of many nutrients, but lower intake of some nutrients to limit and better diet quality; health professionals should encourage the addition of mushrooms to the diet, especially in ways that are prepared with lower levels of sodium.

Keywords: Mushrooms; Nutrient intake; Food group intake; Diet quality; Adults; NHANES

Abbreviations: DV: Daily Value; FCID: Food Commodity Intake Database; HEI-2005: Healthy Eating Index-2005; IU: International Units; mg: microgram; NHANES: National Health and Nutrition Examination Survey; RDA: Recommended Dietary Allowance; UV: Ultra Violet; USDA: United States Department of Agriculture

Introduction

Mushrooms have been consumed as part of the human diet since prehistoric times [1]. Many are edible [1], and, although they are classed botanically as fungi, from a practical, and more importantly, a culinary standpoint, they are considered as vegetables [2]. Recently, they have been informally categorized among the "white vegetables", which have recently been recognized as a "forgotten source of nutrients" [3].

Mushroom intake data are sparse. Over the past 40 years, retail *per capita* availability of mushrooms has more than tripled from only 0.9 pounds/person in 1970 to 3.1 pounds/person in 2010 [4]. These data are limited; however, because they do not assess actual consumption. There are no recent data looking at individual mushroom consumption; however, data from the 1996-1996, 1998 Continuing Survey of Food Intake by Individuals (CSFII) showed that nearly 10% of individuals consumed mushrooms on a given day [5].

Button mushrooms (*Agaricus bisporus*), the most widely consumed mushrooms in the United States, provide a variety of nutrients, including protein, dietary fiber, riboflavin, niacin, potassium, phosphorus, zinc, selenium, and copper to the diet; they also provide provitamin D, which can be converted to vitamin D upon exposure to ultraviolet (UV) light. Mushrooms are also low in energy, total and saturated fatty acids, and

sodium. Different types of mushrooms also vary slightly in nutrient content [6]. Using a serving size of 84 g (3 ounces) [7], the common white button mushroom is a "good" source ($\geq 10\%$ of the Daily Value [DV]) of niacin, pantothenic acid, copper, and selenium, and an "excellent" source ($\geq 20\%$ of the DV) of riboflavin [6].

The single study (unpublished report by Block Dietary Data Systems for the Mushroom Council) suggested that more mushroom consumers compared with non-mushroom consumers participating in the National Health and Nutrition Examination Survey (NHANES) III met the Recommended Dietary Allowance (RDA)/Dietary Reference Intake for: energy; protein; carbohydrate; dietary fiber; vitamins A, E, C, B6, and B12; thiamin; riboflavin; niacin; folate; calcium; copper; iron; magnesium; phosphorus; zinc; and selenium. This suggested that mushroom consumers had a more nutrient-rich diet than non-mushroom consumers. That study also showed that mushroom consumers consumed 5.4 servings of vegetables/day compared with only 3.4 servings/day for non-mushroom consumers. Coupled

***Corresponding author:** Carol E O'Neil, Class of 1941 Alumni Professor, 261 Knapp Hall, LSU Agricultural Center, Baton Rouge, Louisiana 70803, USA, Tel: 225-578-1631; Fax: 225-578-4443; Email: coneil1@lsu.edu

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with their pleasing aroma and taste, their nutritional profile makes mushrooms a desirable food source.

There are no published studies that have looked at mushroom consumption and a potential association with better nutrient intake or diet quality. The purpose of this study was to determine whether there was an association between mushroom consumption and nutrient intake or diet quality.

Subjects and Methods

Study overview, population, and analytic sample

The NHANES is a cross-sectional surveillance program conducted on a continual basis by the National Center for Health Statistics of the Centers for Disease Control and Prevention. A major objective of the NHANES is to examine relationships between diet, nutrition, and health [8]. Detailed descriptions of the survey design, content, operations, and procedures, including study manuals and quality assurance/control methods, can be found elsewhere [9]. For consumption trends, data from NHANES III to 2007-2010 were used. For nutrient intake and diet quality analyses, data from adult (19+ years) participants in the NHANES 2001-2010 were combined to increase sample size [10,11]. Analyses included only individuals with complete and reliable dietary records as determined by the National Center for Health Statistics staff. Females who were pregnant or lactating were excluded from the study. Since this study was a secondary analysis without individual identifiers, institutional review was not required [12].

Dietary intake and nutrient analysis

Dietary data were collected via a single interviewer administered 24-hour dietary recall using an automated multiple-pass method [13,14]. Detailed descriptions of the dietary interview methods are provided in the NHANES Dietary Interviewers Procedure Manual, which includes pictures of the Computer-Assisted Dietary Interview system screens, measurement guides, and charts that were used to collect dietary information [15].

The United States Environmental Protection Agency-USDA Food Commodity Intake Database (FCID) commodity codes [16] were used to determine mushroom consumption. Mushroom intake was

determined using two methods. Consumer Definition 1 was: grams of intake by food code times the weight of mushrooms per 100 g of the food code (n=281). This definition included foods that were mostly mushrooms or mushrooms alone, for example steak with mushrooms served on the side, and mushrooms as a recipe component, for example mushrooms in beef burgundy. Consumer Definition 2 was: grams of mushroom intake from commodity database for food codes (n=32) designated as "mushrooms" or a dish that was mainly mushrooms, for example stuffed mushrooms or sautéed mushrooms. Consumers were defined as those individuals consuming any amount of mushrooms. All consumers in Definition 2 were also designated as consumers in Definition 1. To assess nutrient intake the USDA Food and Nutrient Database for Dietary Studies [17] was used. The Vitamin D Addendum to USDA Food and Nutrient Database for Dietary Studies 3.0 [18] was used to determine vitamin D intake.

Food group equivalents and diet quality

Food group equivalent intakes (formerly called MyPyramid equivalents) were determined using MyPyramid Equivalents Database 1.0 (NHANES 2001-2002) [19] or 2.0 (NHANES 2003-2004) [20]; when necessary, food group equivalent intakes from NHANES 2005-2006 and 2007-2008 were hand matched to similar foods. The Health Eating Index-2005 (HEI-2005) score was used to determine diet quality [21]. The SAS code used to calculate HEI-2005 scores was downloaded from the Center for Nutrition Policy and Promotion website [22].

Statistical analyses

For the initial analyses, SUDAAN v10.0 (Research Triangle Institute; Raleigh, NC) was used to adjust analyses for sampling weights and the sampling units and strata information as provided by NHANES [10,11]. Least-square means (\pm standard errors) were calculated using PROC REGRESS of SUDAAN. Linear regression was used to determine differences in mushroom consumers and non-consumers for nutrients and food groups for each consumer definition of mushrooms. For all linear regressions, covariates were age, gender, ethnicity, poverty index ratio, and physical activity level, smoking status, and alcohol consumption. Demographic information used as covariates was determined from the NHANES interview [23]; alcohol consumption was obtained from the 24-hour recall data. Nutrient and food group

Variable	Consumer Definition 1			Consumer Definition 2		
	Non-Consumer	Consumer	P	Non-Consumer	Consumer	P
	n=22,408	n=2,399		n=24,347	n=460	
	Mean \pm SE	Mean \pm SE		Mean \pm SE	Mean \pm SE	
Age	46.6 \pm 0.3	45.1 \pm 0.4	0.0022	46.5 \pm 0.3	46.1 \pm 1.0	0.7438
Gender—Female (%)	50.6 \pm 0.4	53.0 \pm 1.4	0.0863	50.7 \pm 0.3	57.2 \pm 2.6	0.0131
Non-Hispanic White (%)	70.5 \pm 1.5	78.4 \pm 1.4	0.0001	71.1 \pm 1.5	85.6 \pm 1.8	<0.0001
Non-Hispanic Black (%)	12.0 \pm 0.8	6.0 \pm 0.6	<0.0001	11.5 \pm 0.8	4.4 \pm 0.9	<0.0001
Mexican American (%)	12.6 \pm 1.1	8.6 \pm 0.8	0.0028	12.3 \pm 1.0	5.7 \pm 1.0	<0.0001
Poverty Income Ratio	3.0 \pm 0.0	3.4 \pm 0.1	<0.0001	3.0 \pm 0.0	3.7 \pm 0.1	<0.0001
Smoker Current (%)	24.8 \pm 0.5	20.2 \pm 1.3	0.0015	24.4 \pm 0.6	18.8 \pm 2.4	0.0247
Physical Activity—Sedentary (%)	29.7 \pm 0.6	23.3 \pm 1.3	<0.0001	29.2 \pm 0.6	18.6 \pm 2.2	<0.0001
Physical Activity—Moderate (%)	34.0 \pm 0.5	35.0 \pm 1.4	0.4823	34.0 \pm 0.5	38.5 \pm 2.9	0.1282
Physical Activity—Vigorous (%)	36.3 \pm 0.7	41.7 \pm 1.6	0.0022	36.8 \pm 0.7	43.0 \pm 3.3	0.0629
HS Graduate - No College (%)	25.9 \pm 0.5	20.0 \pm 1.2	<0.0001	25.4 \pm 0.5	18.4 \pm 2.6	0.0076
Attended College (%)	54.4 \pm 0.8	68.4 \pm 1.5	<0.0001	55.6 \pm 0.9	73.6 \pm 2.4	<0.0001
Alcohol Consumer (%)	25.7 \pm 0.7	36.4 \pm 1.1	<0.0001	26.6 \pm 0.7	36.3 \pm 2.9	0.0010
Alcohol (gm/d)	10.9 \pm 0.3	12.3 \pm 0.9	0.1455	11.0 \pm 0.3	11.0 \pm 1.5	0.9901

Table 1: Demographic and Lifestyle Characteristics of the Adults Aged 19+ years Participating in the National Health and Nutrition Examination Survey 2001-2010 Characterized by Mushroom Consumption Definition.

intakes were also adjusted for total energy intake; HEI-2005/HEI-2005 sub-components were not adjusted for energy since scoring based on 1000 calorie basis [21]. Dietary day 1 weights were used for all analyses. Statistical differences for variables of interest were determined via t-test comparing to the no mushroom groups. A probability of $p < 0.01$ was considered significant.

Results

Demographics and mushroom consumption

Subjects were adults 19+ years ($N=24,807$) participating in the NHANES 2001-2010. Using Consumer Definition 1, 9.7% of the population were mushroom consumers; whereas, using Consumer Definition 2, 1.9% of the population were mushroom consumers. Table 1 shows that, using either definition, overall, mushroom consumers were mostly non-Hispanic White, generally younger, had higher incomes, had a lower prevalence of smokers, participated more in vigorous exercise, had a higher level of education, and had a higher prevalence of alcohol consumers, although the amount of alcohol consumed was not different from non-mushroom consumers. In Consumer Definition 2, more females than males consumed mushrooms.

Consumption levels of mushrooms depended on the definition used to identify mushroom consumers. From 2001-2010 consumption of mushrooms was 20.6 ± 0.8 g and 39.5 ± 2.6 g for Consumer Definition 1 and 2, respectively. There was no change in reported mushroom consumption from 1988 to 2010 (Table 2).

Energy, macronutrient, and micronutrient intakes

Using Consumer Definition 1, mushroom consumers had higher ($p < 0.01$) mean intakes of energy (2307 ± 26 v 2162 ± 10 kcal), protein (85.3 ± 0.8 v 82.9 ± 0.3 g), thiamin (1.8 ± 0.0 v 1.6 ± 0.0 mg), niacin (26.0 ± 0.3 v 24.7 ± 0.1 mg), folate (572.8 ± 10.3 v 540 ± 4.2 mg), copper (1.4 ± 0.02 v 1.3 ± 0.0 mg), selenium (118.6 ± 1.4 v 109.7 ± 0.5 mg), and sodium (3773.6 ± 33.1 v 3478.8 ± 11.2 mg) than non-consumers (Table 3). Using Consumer Definition 2, mushroom consumers had higher ($p < 0.01$) intakes of protein (88.5 ± 1.3 g v 83.0 ± 0.3), dietary fiber (17.8 ± 0.5 v 16.0 ± 0.1 g), vitamin E (8.5 ± 0.3 mg v 7.4 ± 0.1), riboflavin (2.4 ± 0.1 v 2.2 ± 0.0 mg), niacin (27.2 ± 0.7 v 24.8 ± 0.0 mg), vitamin C (106.0 ± 6.0 v 87.8 ± 1.3 mg), total choline (364.4 ± 8.8 v 333.6 ± 1.8 mg), copper (1.6 ± 0.0 v 1.3 ± 0.0 mg), potassium (3033.2 ± 57.4 v 2720.7 ± 11.8 mg), selenium (121.8 ± 3.1 v 110.4 ± 0.5 mg), and sodium (3718.3 ± 74.2 v 3507.4 ± 10.1 mg) than non-consumers.

Using Consumer Definition 1, mushroom consumers had lower ($p < 0.01$) intakes of total sugars (115 ± 1.7 v 124.1 ± 0.8 g), added sugars (17.2 ± 0.4 v 19.4 ± 0.2 tsp eq), and zinc (11.6 ± 0.1 v 12.2 ± 0.1 mg) than non-mushroom consumers (Table 3). Using Consumer Definition

2, mushroom consumers had lower ($p < 0.01$) intakes of added sugars (16.3 ± 0.9 v 19.2 ± 0.2 tsp eq) than non-mushroom consumers.

Diet quality

Using Consumer Definition 1, mushroom consumers had a higher ($p < 0.01$) total HEI-2005 score (52.4 ± 0.4 v 51.3 ± 0.2) than non-consumers (Table 4). Mushroom consumers also had higher HEI-2005 component scores for total vegetables (3.5 ± 0.0 v 3.0 ± 0.0), dark green and orange vegetables (1.4 ± 0.0 v 1.2 ± 0.0), total grains (4.4 ± 0.0 v 4.2 ± 0.0), and milk (5.2 ± 0.1 v 4.9 ± 0.1) than non-mushroom consumers. Mushroom consumers had a lower ($p < 0.01$) sodium component score (3.2 ± 0.1 v 4.0 ± 0.0) than non-mushroom consumers. Using Consumer Definition 2, mushroom consumers also had a higher ($p < 0.01$) total HEI-2005 score (54.6 ± 0.9 v 51.4 ± 0.2) than non-consumers. Mushroom consumers also had higher HEI-2005 component scores for total fruit (2.6 ± 0.1 v 2.2 ± 0.0), total vegetables (4.1 ± 0.1 v 3.0 ± 0.0), dark green and orange vegetables (1.8 ± 0.1 v 1.2 ± 0.0), and oils (6.4 ± 0.2 v 5.8 ± 0.0) than non-consumers.

Discussion

This is the first published study showing the association between nutrient intake and diet quality in mushroom consumers. Mushroom consumption was associated with better nutrient intake and diet quality than seen in non-mushroom consumers.

Two separate definitions of mushroom consumers were used in this study. There is concern when examining a food that is frequently used in mixed dishes, such as mushrooms, on how consumers, and consequently consumption levels, of that food should be defined. Should all dishes in which mushrooms were included be considered, even though it is was a minor recipe ingredient and the individual may not have made a conscious effort to consume mushrooms, or should only those who had made a decision to consume mushrooms be considered as consumers? Since there was nothing in the literature that established a precedent, two definitions were used for this study. Consumer Definition 1 contained all foods with mushrooms; whereas, Consumer Definition 2 represented a more deliberate effort on the part of the consumer to consume mushrooms. All individuals in Consumer Definition 2 were also in Consumer Definition 1; however, the antithesis was not the case.

In each Consumer Definition, there were striking differences in the demographics of mushroom consumers and non-mushroom consumers. However, most demographic factors suggested that mushroom consumers had a higher income, more education, and a healthier lifestyle than non-mushroom consumers. This finding was reinforced in that mushroom consumers had better nutrient intakes for many of the nutrients examined and better overall diet quality than non-mushroom consumers.

Mushroom Consumer Definition	Consumption Status	1988-1994	2001-2002	2003-2004	2005-2006	2007-2008	2009-2010	2007-2010	2001-2010	2001-2010	Trend
		Mean \pm SE (g)	Beta	P							
1 ¹	Per-Capita	2.4 \pm 0.2	2.3 \pm 0.2	2.5 \pm 0.3	2.6 \pm 0.3	2.1 \pm 0.2	2.1 \pm 0.2	2.1 \pm 0.1	2.3 \pm 0.1	-0.1	0.2656
1 ¹	Consumer	21.3 \pm 1.1	19.9 \pm 0.9	22.10 \pm 2.6	21.2 \pm 1.3	20.1 \pm 1.9	19.9 \pm 1.3	20. \pm 1.1	20.6 \pm 0.8	-0.2	0.6387
2 ²	Pre-Capita	1.2 \pm 0.2	1.0 \pm 0.2	1.3 \pm 0.3	0.9 \pm 0.2	0.9 \pm 0.1	0.6 \pm 0.1	0.8 \pm 0.1	0.9 \pm 0.1	-0.1	0.0461
2 ²	Consumer	38.1 \pm 3.0	38.4 \pm 3.8	48.6 \pm 8.7	39.0 \pm 4.7	41.6 \pm 5.4	28.6 \pm 3.8	35.2 \pm 3.4	39.5 \pm 2.6	-2.6	0.1031

¹Consumers were defined as: use grams of intake by food code times the weight of mushrooms per 100 grams of the food code ($n=281$) as given in the US Environmental Protection Agency-USDA Food Commodity Intake Database commodity codes

²Consumers were defined as: grams of mushroom intake from the food code ($n=32$) as given in the US Environmental Protection Agency-USDA Food Commodity Intake Database commodity codes

Table 2: Mushroom Consumption by Adults Aged 19+ years Participating in the National Health and Nutrition Examination Survey 2001-2010 Characterized by Mushroom Consumption Definition.

Nutrients ¹	Mushroom Definition 1			Mushroom Definition 2		
	Consumer n=2,399	Non-Consumer n=22,408	P	Consumer n=460	Non-Consumer n=24,347	P
	LSM ± SE ²	LSM ± SE		LSM ± SE	LSM ± SE	
Energy (kcal)	2306.6 ± 25.5	2162.3 ± 9.9	<0.0001	2296.8 ± 48.7	2175.9 ± 9.6	0.0218
Protein (gm)	85.3 ± 0.8	82.9 ± 0.3	0.0051	88.5 ± 1.8	83.0 ± 0.3	0.0037
Total sugars (gm)	115.0 ± 1.7	124.1 ± 0.8	<0.0001	114.3 ± 4.1	123.3 ± 0.8	0.0359
Added Sugar (tspeq)	17.2 ± 0.4	19.4 ± 0.2	<0.0001	16.3 ± 0.9	19.2 ± 0.2	0.0040
Dietary fiber (gm)	16.6 ± 0.2	16.0 ± 0.1	0.0312	17.8 ± 0.5	16.0 ± 0.1	0.0008
Total fat (gm)	82.3 ± 0.6	82.3 ± 0.3	0.9819	85.4 ± 1.5	82.2 ± 0.3	0.0375
MUFA (gm)	30.1 ± 0.3	30.3 ± 0.1	0.2768	31.3 ± 0.7	30.3 ± 0.1	0.1522
PUFA (gm)	17.8 ± 0.2	17.4 ± 0.1	0.1273	18.9 ± 0.6	17.4 ± 0.1	0.0168
SFA (gm)	26.8 ± 0.3	27.1 ± 0.1	0.3782	27.2 ± 0.6	27.1 ± 0.1	0.8832
Cholesterol (mg)	300.9 ± 6.3	285.7 ± 2.2	0.0234	308.6 ± 13.4	286.9 ± 2.1	0.1115
Vitamin A, RAE (mcg)	630.8 ± 16.2	621.3 ± 8.5	0.6264	695.3 ± 40.2	620.6 ± 7.6	0.0738
Vitamin D (mcg)	4.7 ± 0.2	4.7 ± 0.1	0.7490	4.8 ± 0.4	4.7 ± 0.1	0.9187
Vitamin E α-tocopherol (mg)	7.8 ± 0.1	7.4 ± 0.1	0.0278	8.5 ± 0.3	7.4 ± 0.1	0.0042
Thiamin (mg)	1.8 ± 0.0	1.6 ± 0.0	0.0001	1.8 ± 0.1	1.7 ± 0.0	0.1568
Riboflavin (mg)	2.3 ± 0.0	2.2 ± 0.0	0.0193	2.4 ± 0.1	2.2 ± 0.0	0.0090
Niacin (mg)	26.0 ± 0.3	24.7 ± 0.1	0.0006	27.2 ± 0.7	24.8 ± 0.1	0.0014
Vitamin B12 (mcg)	5.2 ± 0.1	5.4 ± 0.1	0.0609	5.5 ± 0.3	5.4 ± 0.1	0.6805
Folate, DFE (mcg)	572.8 ± 10.3	539.9 ± 4.2	0.0027	583.3 ± 31.4	542.7 ± 4.0	0.2053
Vitamin C (mg)	92.7 ± 2.6	87.6 ± 1.4	0.0797	106.0 ± 6.0	87.8 ± 1.3	0.0053
Total choline (mg)	342.1 ± 4.8	333.2 ± 1.8	0.0683	364.4 ± 8.8	333.6 ± 1.8	0.0007
Calcium (mg)	937.4 ± 14.7	932.7 ± 6.3	0.7645	912.6 ± 33.5	933.7 ± 6.0	0.5397
Copper (mg)	1.4 ± 0.0	1.3 ± 0.0	<0.0001	1.6 ± 0.0	1.3 ± 0.0	<0.0001
Iron (mg)	16.0 ± 0.2	15.5 ± 0.1	0.0226	16.2 ± 0.4	15.6 ± 0.1	0.1811
Magnesium (mg)	297.1 ± 3.5	293.1 ± 1.6	0.2958	309.9 ± 7.9	293.2 ± 1.6	0.0464
Phosphorus (mg)	1377.6 ± 13.3	1356.8 ± 4.7	0.1279	1400.2 ± 30.5	1358.2 ± 4.6	0.1727
Potassium (mg)	2724.9 ± 22.5	2728.3 ± 12.7	0.8939	3033.21 ± 57.40	2720.7 ± 11.8	<0.0001
Selenium (mcg)	118.6 ± 1.4	109.7 ± 0.5	<0.0001	121.75 ± 3.14	110.4 ± 0.5	0.0008
Sodium (mg)	3773.6 ± 33.1	3478.8 ± 11.2	<0.0001	3718.28 ± 74.22	3507.4 ± 10.1	0.0061
Zinc (mg)	11.6 ± 0.1	12.3 ± 0.1	<0.0001	12.54 ± 0.36	12.2 ± 0.1	0.3862

¹Adjusted for gender, ethnicity, age, socioeconomic status (PIR 0-1.25, 1.25-3.5, >=3.25), physical activity level (sedentary, moderate, active), current smoking status, and alcohol consumption; nutrients were also adjusted for total energy intake.

²Values are presented as least-square means ± SE.

Table 3: Energy and Nutrient Intake by Adults Aged 19+ years Participating in the National Health and Nutrition Examination Survey 2001-2010 Characterized by Mushroom Consumption Definition.

Variable ¹	Mushroom Definition 1			Mushroom Definition 2		
	Consumer	Non-Consumer	P	Consumer	Non-Consumer	P
	LSM ± SE ²	LSM ± SE		LSM ± SE	LSM ± SE	
Healthy Eating Index-2005 Total Score	52.4 ± 0.4	51.3 ± 0.2	0.0095	54.6 ± 0.9	51.4 ± 0.2	0.0010
Component 1 (Total Fruit)	2.2 ± 0.1	2.2 ± 0.0	0.3159	2.6 ± 0.1	2.2 ± 0.0	0.0044
Component 2 (Whole Fruit)	2.0 ± 0.1	1.9 ± 0.0	0.1503	2.3 ± 0.1	2.0 ± 0.0	0.0313
Component 3 (Total Vegetable)	3.5 ± 0.0	3.0 ± 0.0	<0.0001	4.1 ± 0.1	3.0 ± 0.0	<0.0001
Component 4 (Dark Green & Orange Veg)	1.4 ± 0.0	1.2 ± 0.0	0.0007	1.8 ± 0.1	1.2 ± 0.0	<0.0001
Component 5 (Total Grains)	4.4 ± 0.0	4.2 ± 0.0	<0.0001	4.0 ± 0.1	4.2 ± 0.0	0.0136
Component 6 (Whole Grains)	1.0 ± 0.0	1.1 ± 0.0	0.1250	1.0 ± 0.1	1.1 ± 0.0	0.6699
Component 7 (Milk)	5.2 ± 0.1	4.9 ± 0.1	0.0056	4.8 ± 0.2	5.0 ± 0.1	0.3364
Component 8 (Meat and Beans)	7.9 ± 0.1	8.0 ± 0.0	0.6504	8.3 ± 0.2	8.0 ± 0.0	0.0784
Component 9 (Oils)	5.9 ± 0.1	5.8 ± 0.0	0.3170	6.4 ± 0.2	5.8 ± 0.0	0.0052
Component 10 (Saturated Fat)	5.8 ± 0.1	5.9 ± 0.0	0.7451	5.8 ± 0.2	5.9 ± 0.0	0.7729
Component 11 (Sodium)	3.2 ± 0.1	4.0 ± 0.0	<0.0001	3.5 ± 0.7	4.4 ± 0.1	0.2152
Component 12 (SoFAAS)	9.8 ± 0.2	9.3 ± 0.1	0.0186	10.4 ± 0.4	9.3 ± 0.1	0.0175

¹Adjusted for gender, ethnicity, age, socioeconomic status (PIR 0-1.25, 1.25-3.5, >=3.25), physical activity level (sedentary, moderate, active), current smoking status, and alcohol consumption; nutrients are also adjusted for total energy intake

²Values are presented as least-square means ± SE.

Abbreviation: SoFAAS = solid fat, alcohol, and added sugars

Table 4: Healthy Eating Index-2005 Total Score and Component Scores of Adults Aged 19+ years Participating in the National Health and Nutrition Examination Survey 2001-2010 Characterized by Mushroom Consumption Definition.

Unsurprisingly, the level of mushroom consumption was considerably different between the two definitions, with those in Consumer Definition 2 having the higher intake among consumers. There were also differences in the nutrient intakes between mushroom consumers, as defined by the two definitions, when compared with their corresponding non-consumer group. Both consumer definitions showed that many micronutrients were higher in mushroom consumers than in non-mushroom consumers. Especially important was that mushroom consumers in both definitions had lower intakes of added sugars. Micronutrient intake varied by consumer definition, but overall in each mushroom consumption group, intake of most micronutrients was higher than seen in non-mushroom consumers. These were generally positive; including vitamin E, many B vitamins, copper, total choline, and selenium. Those in the Consumer Definition 2 group also had higher potassium intake.

However, sodium intake was higher in both definitions of mushroom consumers than in the corresponding non-mushroom consumer groups; sodium intake was higher in consumers by nearly 300 mg/d when Consumer Definition 1 was used and sodium intake was slightly more than 200 mg/d higher when Consumer Definition 2 was used. Mushrooms are a very low sodium food; thus, it was likely that foods consumed with the mushrooms or salt added during the preparation of mushroom dishes resulted in the higher sodium intakes. This was not surprising since mushrooms are often recipe items in high sodium foods [6], especially pizza, mixed Asian-style dishes, soups, and other prepared foods. This high sodium intake was reflected in the HEI-2005 component score for sodium, where mushroom consumers in Consumer Definition 1 had a lower score than non-mushroom consumers. Although the difference in sodium intake seen among those in Consumer Definition 2 was significant, it is probable that the difference was not enough to be reflected in the HEI-2005 component scores.

It should also be noted that the HEI-2005 component scores for nutrients to limit, SFA, sodium, and solid fat, alcohol, and added sugars, are reversed when compared with the food groups to encourage, with a higher score reflecting a better nutrient intake. For example, with sodium, a perfect HEI-2005 component score of 10.0 would reflect a sodium intake of only 1,500 mg/day [21]. Thus, it is appropriate that although sodium intake was higher in mushroom consumers, the HEI-2005 component score was lower.

Especially noteworthy among the micronutrients was that vitamin D intake was not different between mushroom consumers and non-mushroom consumers. Vitamin D has been classified as a nutrient of public health concern by the 2010 Dietary Guidelines for Americans [24]. The RDA for vitamin D in adults, which assumes minimal sun exposure, is 600 IU (15 mg)/day for most adults and 800 IU (20 mg) for adults older than 70 years [24]. Intakes seen in this study were less than one half of the recommendations in males and less than one third in females. Some common edible varieties of mushrooms are rich natural sources of vitamin D, with concentrations of up to 59 mg/100 g fresh weight [25]. However, when exposed to sunlight or UV light, ergosterol, the most abundant phytochemical in mushrooms [26,27] undergoes photolysis and yields previtamin D₂, tachysterol, and lumisterol. Previtamin D₂ then undergoes spontaneous thermal rearrangement to vitamin D₂ [28]. The amount of vitamin D in mushrooms treated with UV light can increase dramatically; for example 85 gm of a raw portabella mushroom provides only 0.3 mg of vitamin D; whereas, the same serving size that has been exposed to UV light provides 9.5 mg vitamin D or nearly half of the RDA for adults [6].

Why then was the intake of vitamin D among mushroom consumers not higher than non-mushroom consumers in this study? Vitamin D and sterol levels were recently collected on 10 types of mushrooms commonly retailed in the US, with the goal of updating the USDA Nutrient Database [29], suggesting the most current information on vitamin D content is available. However, mushroom species commonly consumed in the US, including white button mushrooms, criminis, and non-UV light treated portabellas were relatively poor sources of vitamin D [29]. Moreover, not all mushrooms are UV light treated; and consumers may not know or recall if their mushrooms were UV light treated. This may be especially true of mushrooms consumed in a restaurant setting, where they would have no way to know if the mushrooms had been UV light treated. More widespread UV light treatment of mushrooms would provide an excellent source of this nutrient of public health concern.

Regardless of how mushroom consumers were defined, diet quality was higher among consumers than non-consumers. Both definitions of consumers had higher intakes of total vegetables, dark green and orange vegetables, and total grains. Consumer Definition 1 consumers also had higher HEI-2005 component score for milk, perhaps reflecting that pizza with cheese was the third most common food consumed with mushrooms (data not shown). The oil sub-component was also higher in those in Consumer Definition 2. Since mushrooms have virtually no fat, these findings may reflect foods consumed with mushrooms, oils added during preparation, or at the table, for example in a salad with mushrooms. Mushroom consumers defined by Consumer Definition 2, also had higher intakes of total fruit; along with higher intakes of vegetables, which may have contributed to the higher potassium intake seen in this group. Intake of fruit and vegetables is low in all groups in the US [30]; therefore, consumption of mushrooms should be encouraged.

Limitations

A principal limitation of this study is that cross-sectional studies cannot be used to determine cause and effect. Thus, any positive or negative findings may be the result of foods consumed with mushrooms or may reflect how the mushrooms were prepared. Twenty-four hour dietary recalls have several inherent limitations. Participants rely on memory to self-report dietary intakes; therefore, data are subject to non-sampling errors, including underreporting of energy and examiner effects. The one-day intake used in this study may not represent usual intake of individuals over time. However, a single 24-hour dietary recall is appropriate when reporting mean group intakes [31]. The choice was made to use a single 24-hour dietary recall when the 2001-2002 data sets were included in the analyses to assure adequate sample size; at that time, only NHANES collected only one day of dietary data. Due to multi-collinearity of diet, foods other than mushrooms may have contributed to differences in nutrient intake of the participants. This may be especially true for foods that did not contribute substantial amounts of mushrooms, like some mushroom soups.

Conclusions and Recommendations

Mushroom consumption, regardless of the way it was defined, was associated with a better nutrient profile and diet quality than that seen in non-consumers. Mushroom consumption should be encouraged by health professionals, including registered dietitians; nutrition education programs that increase awareness and consumption of mushrooms should be designed and delivered. Ways to prepare mushrooms without sodium should be emphasized in consumer messages. Consumers should also be encouraged to seek out UV light treated mushrooms

to help increase vitamin D intake in the diet. Further studies are needed to confirm these results and to determine the association of mushroom consumption with health risk markers, including obesity, cardiovascular risk factors, and metabolic syndrome.

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References

- Davidson A (1999) *The Oxford Companion to Food*. New York. Oxford University Press.
- United States Department of Agriculture (2013) MyPlate.
- Weaver C, Marr ET (2013) White vegetables: a forgotten source of nutrients: Purdue roundtable executive summary. *Adv Nutr* 4: 318S-326S.
- United States Department of Agriculture (2013) Economic Research Service. Food Availability Per Capita Data System.
- Lucier G, Allshouse J, Lin B-H (2003) Factors Affecting U.S. Mushroom Consumption. *Economic Research Publication VGS 295-301*.
- United States Department of Agriculture (2013) Agricultural Research Service. USDA National Nutrient Database for Standard Reference.
- Federal Food and Drug Administration (2013) Food Labeling Information, Raw Vegetables.
- National Health and Nutrition Examination Survey (2013) About the National Health and Nutrition Examination Survey.
- National Health and Nutrition Examination Survey (2013) Questionnaires, Datasets, and Related Documentation.
- National Health and Nutrition Examination Survey (2013) Analytic and Reporting Guidelines.
- National Health and Nutrition Examination Survey (2013) Analytic Note Regarding 2007-2010 Survey Design Changes and Combining Data Across other Survey Cycles.
- US Department of Health & Human Services (2013) National Institutes of Health, Office of Extramural Research.
- Moshfegh AJ, Rhodes DG, Baer DJ, Murayi T, Clemens JC, et al. (2008) The US Department of Agriculture Automated Multiple-Pass Method reduces bias in the collection of energy intakes. *Am J Clin Nutr* 88: 324-332.
- Blanton CA, Moshfegh AJ, Baer DJ, Kretsch MJ (2006) The USDA Automated Multiple-Pass Method accurately estimates group total energy and nutrient intake. *J Nutr* 136: 2594-2599.
- National Health and Nutrition Examination Survey (2013) MEC In-Person Dietary Interviewers Procedures Manual.
- Welcome to the U.S. EPA's (2009) What We Eat in America - Food Commodity Intake Database, 2003-2008 (WWEIA-FCID 2003-08).
- United States Department of Agriculture (2013) Food and Nutrient Database for Dietary Studies.
- United States Department of Agriculture (2013) Agricultural Research Service. Food and Nutrient Database for Dietary Studies. Vitamin D Addendum to USDA Food and Nutrient Database for Dietary Studies 3.0.
- United States Department of Agriculture (2013) MyPyramid Equivalent Database 1.0.
- United States Department of Agriculture (2013) Agricultural Research Service. MyPyramid Equivalent Database 1.0.
- Guenther PM, Reedy J, Krebs-Smith SM, Reeve BB, Basiotis PP (2013) Development and Evaluation of the Healthy Eating Index-2005: Technical Report. Center for Nutrition Policy and Promotion, USDA.
- USDA (2013) Center of Nutrition Policy and Health Promotion
- National Health and Nutrition Examination Survey. NHANES 2009-2010 Questionnaire Data.
- United States Department of Agriculture (2010) Dietary Guidelines for Americans.
- Teichmann A, Dutta PC, Staas A, Jägerstad M (2007) Sterol and vitamin D2 concentrations in cultivated and wild grown mushrooms: effects of UV irradiation. *LWT - Food Sci Technol* 40: 815-822.
- Mattila PH, Lampi A-M, Ronkainen R, Toivo J, Piironen V (2002) Sterol and vitamin D2 contents in some wild and cultivated mushrooms. *Food Chem* 76: 293-298.
- Mattila P, Salo-Väänänen P, Könkö K, Aro H, Jalava T (2002) Basic composition and amino acid contents of mushrooms cultivated in Finland. *J Agric Food Chem* 50: 6419-6422.
- Mattila PH, Piironen V, Uusi-Rauva EJ, Koivistoinen PE (1994) Vitamin D contents in edible mushrooms. *J Agric Food Chem* 42: 2449-2453.
- Phillips KM, Ruggio DM, Horst RL, Minor B, Simon RR, et al. (2011) Vitamin D and sterol composition of 10 types of mushrooms from retail suppliers in the United States. *J Agric Food Chem* 59: 7841-7853.
- Krebs-Smith SM, Guenther PM, Subar AF, Kirkpatrick SI, Dodd KW (2010) Americans do not meet federal dietary recommendations. *J Nutr* 140: 1832-1838.
- Thompson FE, Byers T (1994) Dietary assessment resource manual. *J Nutr* 124: 2245S-2317S.